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Performance characteristics of mercerized ring- and compact- spun yarns produced at varying level of twist and traveller weight

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The performance characteristics of ring- and compact-spun yarns have been compared at varying level of tex twist factor, yarn linear density and traveller weight. It is observed that the ring yarns are comparatively softer due to the lower flexural rigidity. On the other hand, compact-spun yarns perform better in respect of abrasion resistance, tensile strength, knot strength, loop strength and breaking extension. The loss in tensile strength is higher when the yarn is looped as compared to that when the yarn is knotted; however, in both the cases the loss is found to be marginally lower for compact-spun yarns. Further, the effect of mercerization on all these characteristics of both the yarns is found to be more pronounced in compact-spun yarns and the yarns spun at low twist factors.

Keywords: Compact spinning, Knot strength, Loop strength, Mercerization, Traveller weight, Yarn twist
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1 Introduction

The behaviour of yarns in the subsequent processes and end products is decisively influenced by their performance characteristics. These characteristics can be optimally adapted to the quality requirements by varying physical and technological parameters of the spinning process. Various chemical treatments are also in existence to improve the performance characteristics. Among these, mercerization is of major interest to the researchers as it improves the processing quality of the yarns and the quality of products produced from them. Extensive knowledge and experience on this subject already exists as there are numerous publications reported by various researchers.[1-14]

Compact spinning is an improvement over ring spinning system that has recently been developed. The yarns spun by this system have been reported to be superior to ring-spun yarns.[15-17] Their running behaviour during downstream processing stages as well as the wear properties of the end products produced from them has been found to be favourable[18-24] due to their superior quality in terms of better tensile strength and elongation, reduced hairiness and higher abrasion resistance. Though a few researchers[23,24] have reported that the dyes do not penetrate into the yarn core and are deposited on the surface only, the work in the field of chemical treatments in relation to processing parameters and their effect on processing performance of compact yarns is scanty.[21,23] In this connection, an understanding of the behaviour of mercerized yarns is of fundamental importance and would be worthwhile to be studied. The present study was, therefore, aimed at investigating the influence of tex twist factor, yarn linear density and traveller weight on the performance characteristics of mercerized ring- and compact-spun cotton yarns.

2 Materials and Methods

2.1 Preparation of Yarn Samples

Bunny Brahma cotton (2.5% span length, 30.15 mm; micronaire value 3.31; bundle strength at 3 mm gauge length, 22.81 g/tex and breaking extension 5.54%) was processed through Trutzschler blow room line, Trutzschler DK-760 card, Toyoda DYH-800 draw frame (predrawing), Toyoda TS-100 super lapper, Toyoda E-60 H comber, Rieter RSB-951 (post drawing), and Simplex FL-16 to produce rove of 590.5 tex. The rove was then spun into yarns of two different linear densities, viz. 16.24 tex and 12.74 tex at three different levels of tex twist factor, viz. 34.54, 39.33 and 44.11 on Rieter K-44 Compact spinning frame. Similar yarns were also spun on conventional Rieter G-5/1 ring frame. For a particular set of yarns on both the spinning frame, ring traveller size was

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also varied. The list of yarn samples produced and corresponding variables are given in Table 1.

For mercerization, yarn hanks of suitable length were stretched to normal length on a wooden frame and kept in a 27% NaOH concentration for 1min at room temperature. After this, the hanks were removed from the frame, rinsed, washed and air dried.

2.2 Test Methods

Single yarn strength and breaking elongation were measured on an Instron tensile tester (Model 4411) using a traverse speed of 200 mm/min at 500mm gauge length.

Ring loop method as suggested by Peirce[25] was used for measuring flexural rigidity of different yarn samples. The ASTM standard test method D3885 was followed for measuring flex abrasion resistance.

The yarn diameter was measured by using LEICAQ500MC image analyzer. Yarn was creeled under uniform tension through a disc type tensioner attached to the machine, so as to keep yarn straight under the testing head. After adjusting the focus, the diameter was recorded from the magnified image of yarn. Fifty observations were taken for each sample.

Knot and loop tests were carried out following British standard test method BS 1932: Part 2:1966.

3 Results and Discussion

3.1 Tenacity

Table 2 shows the tenacity values of different yarn samples. In conformity with other researchers[15-17], compact yarns exhibit higher tenacity than their ring-spun counter parts. The influence of all the process

Table 1 — Yarn samples and corresponding variables

Yarn ref. no.	Type of yarn	Yarn linear density tex	Tex twist factor	Traveller No.	Traveller Weight mg
S_1	Ring-spun	16.40	34.54	10/0	22.2
S_2			39.33	10/0	22.2
S_3			44.11	10/0	22.2
S_4		12.84	34.54	10/0	22.2
S_5			39.33	10/0	22.2
S_6			44.11	10/0	22.2
S_7			39.33	7/0	27.8
S_8			39.33	12/0	17.9
S_9	Compact-spun	16.40	34.54	10/0	22.2
S_{10}			39.33	10/0	22.2
S_{11}			44.11	10/0	22.2
S_{12}		12.84	34.54	10/0	22.2
S_{13}			39.33	10/0	22.2
S_{14}			44.11	10/0	22.2
S_{15}			39.33	7/0	27.8
S_{16}			39.33	12/0	17.9

Table 2 — Influence of tex twist factor, linear density and mercerization on tenacity and breaking extension of ring- and compact–spun yarns

Yarn ref. no.	Tenacity, g/tex			Breaking extension, %		
	Grey	Mercerized	% Change	Grey	Mercerized	% Change
S_1	17.80 (6.89)	18.61 (7.40)	+ 4.55	5.44 (7.97)	5.42 (9.81)	– 0.36
S_2	18.67 (7.66)	19.12 (7.70)	+ 2.41	6.02 (7.90)	5.97 (10.17)	– 0.83
S_3	19.24 (6.29)	19.55 (7.77)	+ 1.61	6.52 (6.87)	6.37 (7.73)	– 2.30
S_4	17.32 (6.97)	18.26 (7.09)	+ 5.43	4.30 (8.24)	4.10 (8.69)	– 4.65
S_5	17.83 (5.90)	18.52 (6.82)	+ 3.87	4.67 (8.48)	4.37 (7.86)	– 6.42
S_6	18.11 (7.85)	18.65 (8.23)	+ 2.98	5.23 (9.06)	4.80 (8.30)	– 8.22
S_7	18.18 (7.56)	18.99 (9.62)	+ 4.45	4.43 (9.79)	4.25 (8.49)	– 4.06
S_8	17.07 (6.51)	17.84 (8.32)	+ 4.32	4.99 (6.47)	4.47 (9.59)	–10.42
S_9	19.14 (6.49)	19.76 (6.71)	+ 3.24	5.87 (5.60)	5.74 (7.12)	– 2.21
S_{10}	20.87 (5.40)	21.29 (7.89)	+ 2.01	6.25 (7.86)	6.09 (8.64)	– 2.56
S_{11}	21.72 (6.89)	22.03 (7.93)	+ 1.43	6.73 (7.88)	6.29 (9.12)	– 6.53
S_{12}	18.63 (6.54)	19.50 (8.50)	+ 4.67	5.60 (7.50)	5.30 (7.25)	– 5.36
S_{13}	20.14 (6.97)	20.72 (8.45)	+ 2.87	5.84 (9.24)	5.44 (9.55)	– 6.85
S_{14}	20.74 (6.51)	21.00 (7.82)	+ 1.25	6.45 (6.46)	5.88 (8.08)	– 8.84
S_{15}	21.62 (6.45)	22.04 (7.46)	+ 1.94	5.60 (8.34)	5.37 (8.78)	– 4.11
S_{16}	20.58 (6.21)	21.01 (8.64)	+ 0.62	6.57 (8.62)	5.85 (9.69)	–10.95

Figures in parentheses indicate CV%.

variables, viz. tex twist factor, yarn linear density, traveller weight and mercerization, on yarn tenacity is found to be similar for both types of yarns. The strength increases with all the variables. However, the extent of effectiveness is different. It may be observed that the % difference between the tenacity values of two types of yarns is lower for coarser yarn but shows an increasing trend with the increase in tex twist factor and decrease in traveller weight. The effect of mercerization is found to be less pronounced in yarns spun at higher twist factor. The same is the case with the compact yarns as the % improvement in strength of these yarns after mercerization is found to be less as compared to ring yarns.

Higher tenacity of compact yarns is obviously due to the better integration of fibres, resulting in effective and better utilization of fibre characteristics in these yarns. Besides, the same may also be ascribed to improved fibre binding caused by lateral condensation of fibres by pneumatic forces. This fibre binding is expected to improve further with the increase in tex twist factor. One may also confirm this assertion from measured values of yarn diameter shown in Table 3. With more number of fibres in the yarn cross-section in case of coarser yarns, the improvement in fibre binding with pneumatic compaction or increased twist is probably less, and hence a lower percentage difference in tenacity values. Similar explanation may also be provided for the variation in tenacity with traveller weight. The improvement in tenacity as a result of mercerization may be attributed to improved fibre binding or packing caused by swelling of fibres.[1,2,4] However, the greater compactness arising from higher twist or lateral compaction in compact spinning probably restricts the accessibility of caustic liquor to axial fibres making the effect less pronounced.

3.2 Breaking Extension

Table 2 shows that the yarn breaking extension is significantly affected by all the process variables. It increases with the increase in yarn tex and tex twist factor but is negatively influenced by mercerization and increase in traveller weight. The influence of mercerization is more marked in compact yarns as can be seen from the table. Compared to ring yarns, compact yarns show higher values of extension in all the cases.

Breaking extension of a spun yarn is basically related to the fibre extension and the way fibres are arranged in its body. Compact-spun yarns are characterized by better fibre integration[15,16] and uniform fibre arrangement[26] that probably lead to greater contribution of intrinsic fibre extension to yarn extension. However, the effectiveness of compact spinning system decreases when the yarn becomes coarser. This is due the fact that there occurs a reduction in suction force per unit fibre that is available for compaction in the condensing zone.[17] The reduced force is unable to control and straighten each individual fibre, thereby increasing the number of curled fibres in the yarn and consequently the yarn breaking extension.

Increase in breaking extension with tex twist factor is obviously due to the increased helical configurations of the fibres at higher twist. In regard to the effect of traveller weight, the lower extension may be attributed to the removal of original curliness of fibres as a consequence of increase in spinning tension caused by the increased traveller weight. The loss in extensibility after mercerization is believed to be due to mercerization tension and extension loss during skein formation.[10] Further, the same mercerization tension may cause more stretch in the yarns with higher twist contraction than those with low twist contraction so that these yarns when mercerized and dried show greater length than before. Twist contraction is said to be higher in compact-spun yarns.[20] For this reason, compact yarns and yarns spun with higher twist factor exhibit a greater loss in breaking extension.

3.3 Abrasion Resistance

Table 3 shows that the compact yarns possess higher abrasion resistance than the corresponding ring yarns. It is clear that abrasion resistance of both types of yarns increases with tex twist factor and linear density but decreases dramatically after mercerization. Comparison of data for the two sets of yarns reveals that % difference between abrasion resistance of ring and compact yarns is more for finer yarns and heavier traveller, however it decreases with tex twist factor. The effect of mercerization is similar for both yarns but % change is found to be less for compact yarns, which further decreases with tex twist factor and linear density.

Higher abrasion resistance of compact yarns may be due to the higher compactness, which increases the fibre cohesion and offers better resistance to plucking action of abradent. Higher tex twist factor further increases the compactness of the yarn. Due to less fibres in the yarn cross-section, pneumatic

Table 3 — Influence of tex twist factor, linear density and mercerization on abrasion resistance, flexural rigidity and diameter of ring- and compact–spun yarns

Yarn ref. no.	Abrasion resistance, cycles			Flexural rigidity, dyne-cm^2			Diameter, μm		
	Grey	Mercerized	% Change	Grey	Mercerized	% Change	Grey	Mercerized	% Change
S_1	218 (9.99)	189 (4.65)	–13.28	0.79 (16.09)	0.97 (11.55)	+22.79	175.60 (12.86)	149.14 (4.74)	–15.07
S_2	395 (5.95)	352 (4.30)	–10.97	0.90 (13.09)	1.09 (10.11)	+20.81	169.42 (6.14)	141.71 (5.21)	–16.35
S_3	519 (3.11)	470 (1.70)	– 9.47	0.94 (14.23)	1.13 (9.04)	+20.55	165.56 (11.70)	133.83 (4.18)	–19.16
S_4	169 (4.35)	145 (4.24)	–14.18	0.66 (13.43)	0.80 (8.70)	+19.81	152.99 (5.28)	135.99 (4.32)	–11.11
S_5	262 (6.13)	228 (4.87)	–12.97	0.73 (16.66)	0.86 (10.71)	+17.80	147.24 (9.53)	126.27 (3.94)	–14.24
S_6	417 (2.73)	364 (4.00)	–12.89	0.89 (11.29)	1.01 (8.72)	+12.90	140.88 (7.57)	115.45 (4.32)	–18.54
S_7	177 (8.30)	154 (3.63)	–13.07	0.76 (15.82)	0.89 (6.84)	+17.10	148.48 (8.53)	119.18 (5.02)	–15.35
S_8	228 (4.14)	209 (7.51)	– 8.26	0.70 (14.34)	0.84 (10.71)	+19.87	140.79(8.53)	127.64 (4.25)	–14.03
S_9	286 (6.74)	260 (2.65)	– 9.14	0.90 (11.64)	1.05 (11.29)	+16.23	169.90 (5.38)	141.01 (5.18)	–17.0
S_{10}	442 (7.33)	409 (3.91)	– 7.54	0.98 (16.32)	1.12 (9.38)	+14.48	162.84 (7.18)	134.01 (5.18)	–17.70
S_{11}	566 (4.77)	530 (4.68)	– 6.38	1.02 (15.42)	1.16 (6.74)	+14.08	157.49 (8.27)	124.84 (7.31)	–20.73
S_{12}	237 (5.20)	205 (5.35)	–13.46	0.79 (15.25)	0.87 (7.52)	+10.11	147.26 (7.35)	130.29 (6.35)	–11.52
S_{13}	321 (4.29)	282 (2.51)	–12.25	0.86 (19.55)	0.94 (7.71)	+ 9.57	140.96 (11.02)	120.07 (3.84)	–14.81
S_{14}	489 (2.92)	430 (2.21)	–12.09	0.99 (15.79)	1.08 (13.19)	+ 9.23	136.24 (6.74)	110.64 (4.27)	–18.79
S_{15}	242 (4.95)	212 (4.02)	–12.41	0.90 (17.94)	0.98 (9.94)	+ 8.24	136.20 (10.33)	114.86 (2.81)	–15.67
S_{16}	267 (6.97)	250 (3.56)	– 6.43	0.77 (11.92)	0.87 (10.82)	+13.59	143.22 (12.25)	122.88 (5.12)	–14.19

Figures in parentheses indicate CV%.

compactness is more effective for finer yarns; hence % difference between the ring- and compact-spun yarns is more for finer count. The same may also be true for traveller weight. The loss in abrasion resistance after mercerization may be due to the changes in surface characteristics of the yarn. Higher compactness of compact yarns, which further increases with twist may reduce the liquor penetration in these yarns, thus making the effect less pronounced in compact yarns and high twisted yarns.

3.4 Flexural Rigidity

Table 3 shows that the flexural rigidity of both ring- and compact-spun yarns is significantly affected by yarn linear density, tex twist factor and traveller weight. As is evident, it exhibits increasing trend with all the three variables. Expectedly, it is found to be higher for compact- spun yarns compared to ring-spun yarns in each case. Mercerization also follows a similar relationship, mercerized yarns possessing higher flexural rigidity than the unmercerized ones. However, the percentage increase in flexural rigidity after mercerization is found to be more for ring yarns.

Flexural rigidity is closely related to freedom of fibre movement during bending. Increase in inter fibre cohesion as a result of higher compactness, increased packing density, more number of fibres in yarn cross-section and higher radial pressure restrict the freedom of fibre movement, thus leading to higher flexural rigidity. In case of coarser yarn, a large diameter of the yarn itself may also contribute significantly to the higher values of flexural rigidity. During mercerization, comparatively compact structure of compact- spun yarn does not allow easy access of alkaline liquor to yarn core, thus resulting in a lower % increase in flexural rigidity.

3.5 Knot and Loop Strength

The results of knot strength and loop strength are given in Table 4. Here also, compact yarns are found to be superior to ring yarns. As can be seen from the values of knot strength ratio and loop strength ratio, the loss in tensile strength in majority of cases is marginally higher for ring yarns as against compact yarns, probably due to the structural differences. The loss in tensile strength is also observed to be higher when the yarn is looped as compared to that when the yarn is knotted. As far as the effect of mercerization is concerned, it is found to be significant both at 5% and 1% levels of significance. While knot strength ratio for mercerized yarn lies in the range of 0.73-0.84, the same for loop strength ratio is 0.56-0.73, thereby indicating a loss of 16-27% after mercerization in the former and 27-44% in the later case respectively.

Table 4 — Influence of tex twist factor, linear density and mercerization on knot and loop strengths of ring- and compact- spun yarns

Yarn ref. no.	Knot strength, g/tex		Knot strength ratio		Loop strength, g/tex		Loop strength ratio	
	Grey	Mercerized	Grey	Mercerized	Grey	Mercerized	Grey	Mercerized
S_1	15.46 (5.67)	15.36 (7.92)	0.87	0.83	28.81 (6.23)	23.97 (11.97)	0.81	0.64
S_2	17.74 (7.28)	15.38 (9.58)	0.95	0.80	32.60 (8.19)	25.26 (12.52)	0.87	0.66
S_3	17.50 (6.80)	15.47 (8.85)	0.91	0.79	32.90 (9.84)	23.89 (10.96)	0.86	0.61
S_4	16.39 (9.52)	14.13 (7.66)	0.95	0.77	30.11 (12.18)	20.52 (9.15)	0.87	0.56
S_5	17.70 (7.03)	15.24 (8.47)	0.99	0.82	32.51 (9.59)	24.53 (9.16)	0.91	0.66
S_6	18.00 (8.71)	14.80 (9.11)	0.99	0.79	33.19 (8.26)	24.03 (8.98)	0.92	0.64
S_7	16.49 (7.70)	13.95 (13.04)	0.91	0.73	29.41 (10.15)	23.56 (10.37)	0.81	0.62
S_8	16.82 (8.08)	13.43 (9.04)	0.98	0.75	30.30 (8.18)	24.33 (10.55)	0.89	0.68
S_9	18.70 (8.72)	15.56 (5.55)	0.98	0.79	36.19 (9.37)	27.42 (10.47)	0.95	0.69
S_{10}	19.49 (6.72)	17.02 (8.24)	0.93	0.80	38.07 (8.63)	27.94 (9.06)	0.91	0.66
S_{11}	19.83 (7.00)	17.41 (6.89)	0.91	0.79	38.72 (9.34)	30.87 (9.13)	0.89	0.70
S_{12}	18.50 (5.25)	16.25 (6.54)	0.99	0.83	34.50 (8.62)	24.15 (8.25)	0.93	0.62
S_{13}	19.94 (4.51)	17.26 (6.28)	0.99	0.83	36.90 (8.93)	27.44 (8.93)	0.92	0.66
S_{14}	19.78 (6.22)	17.62 (8.88)	0.95	0.84	35.47 (6.37)	30.53 (8.44)	0.86	0.73
S_{15}	19.95 (5.54)	16.38 (7.90)	0.92	0.74	37.48 (6.86)	27.40 (10.59)	0.87	0.62
S_{16}	19.87 (4.51)	16.82 (7.62)	0.97	0.80	36.53 (6.35)	29.19 (8.56)	0.89	0.69

Figures in parentheses indicate CV%.

Though the knot and loop strengths follow more or less the same trend as that of tensile strength in relation to other variables, viz. tex twist factor, yarn linear density and traveller weight, the influence of yarn linear density and traveller weight on both knot and loop strength ratios is found to be insignificant at 5% level of confidence; that of tex twist factor however does not follow any particular trend.

Knot strength and loop strength generally determine the flexibility and brittleness of the yarns. In general, a reduction in these parameters is to be expected with decreasing extensibility related to mercerization and increasing brittleness.[9]

4 Conclusions

4.1 Compact yarns exhibit higher tenacity which increases with all the variables, viz. tex twist factor, yarn linear density, traveller weight and mercerization. The effect of mercerization is more pronounced for ring-spun yarns and for the yarns spun at low twist factor.

4.2 Compact yarns show higher breaking extension as compared to ring yarns which increases with tex twist factor and yarn tex but is negatively influenced by mercerization and increase in traveller weight.

4.3 Abrasion resistance is higher in case of compact-spun yarns, which further improves with yarn linear density and tex twist factor. Mercerization causes a reduction in abrasion resistance of yarns, the loss being more for ring-spun yarns than for compact-spun yarns.

4.4 Flexural rigidity of both ring- and compact-spun yarns is significantly increased by yarn linear density, tex twist factor, traveller weight and mercerization. It is found to be higher for compact-spun yarns in each case. The percentage increase in flexural rigidity after mercerization is found to be more for ring-spun yarns.

4.5 The loss in tensile strength is higher when the yarn is looped as compared to that when the yarn is knotted. However, this loss in tensile strength by knot and loop formation in majority of cases is marginally lower for compact-spun yarns. The % loss in tensile strength increases with mercerization. The influence of other process parameters, viz. linear density and traveller weight is found to be insignificant.

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